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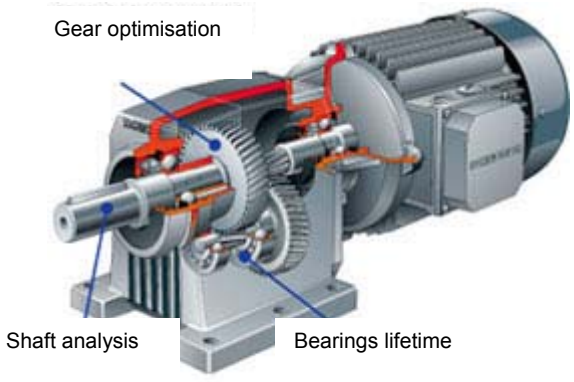
KISSsys application:

Managing variants of two-stage, co-axial gearboxes



1 Task description

A series of about 200 gearboxes shall be represented in a single analysis model. The gearboxes differ by their total reduction and by the type of input shaft. The gearboxes are stored like in a database, managed by an administrator. Using a user interface for the administrator, new variants of the gearbox can be created.
The user has access to this database in order to perform life time calculation of the gearboxes using customer-specific loads, load spectrums and lubrication data.
It is the objective to provide the sales support and the technical office with a tool for automatic and fast strength and lifetime calculations of all involved elements (gears, bearings, shafts and others).

Customer	Supplier	Project	Document
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2 Solution

The core element of the KISSsys model is a table where all gearboxes used are described through definition of their properties, e.g. gear data, shaft geometries, lubricant (database). The database is modified through using an interface where the administrator can define a new variant of a gearbox from single parts. Existing variants can be modified in the same manner.
In a second user interface, the user can select a gearbox to be analysed, define loads and lubrication and execute the lifetime calculation based on a selected load spectrum.
On execution of the analysis, KISSsys calculates the kinematics of the gearbox in order to determine the loads on the machine elements present. After that, KISSsoft analyses the lifetime of the machine elements using these loads and returns strength and lifetime information to be displayed in the same user interface.

3 Description of the model

3.1 Structure of the gearbox

A simple co-axial, two stage helical gearbox is analysed. The intermediate shaft can be arranged in an angle with respect to the other two shafts. All three shafts are supported by fixed and free roller bearings.

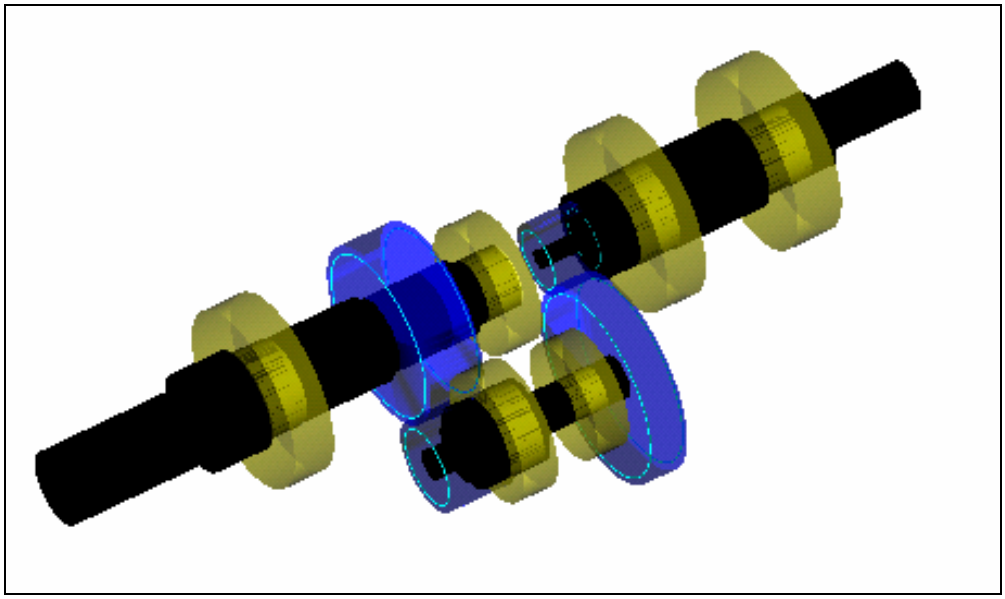

Figure 3.1-1 Structure of the gearbox: Black: shafts, blue: gears, yellow: roller bearings

In addition to the torque, radial/axial forces and bending moments are present on the input and the output shaft.

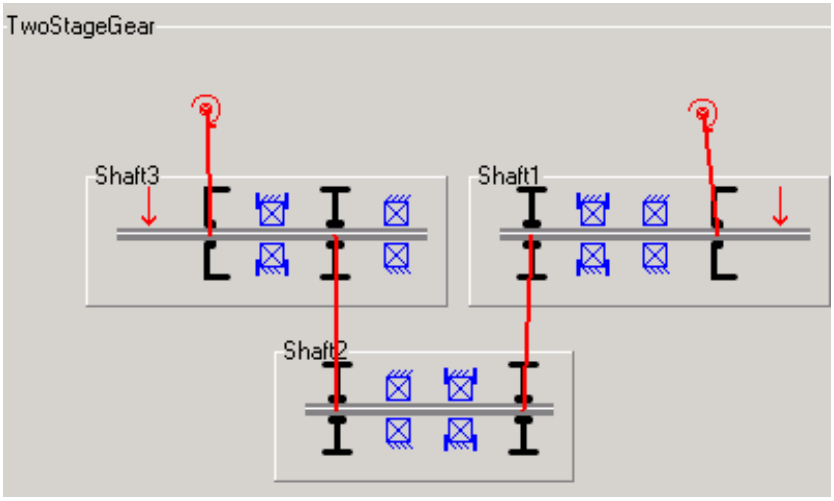

Figure 3.1-2 Scheme of the gearbox including power flow (red), machine elements (shafts, gears, couplings, bearings) and external forces on the input and output shaft

3.2 Structure of the Database

The properties of the gearboxes are stored in a variants table. The following properties are given there:
Variant name
Gear pair, first stage
Gear pair, second stage
Geometry of the shafts
Type and size of the bearings
Position of the gears and bearings on their respective shaft
Relative position of the shafts

The shaft geometries and the gear pair data are stored in KISSsoft files. The different variants of the gearbox are being managed by an administrator, using the interface shown below:

AdminUserInterface

Modify Gearbox	New Gearbox	Accept Data	Stage 1	Stage 2	Input shaft	Intermediate shaft	Output shaft
Gear Variant	Comment	Reduction Code	Select Red. 1	Select Red. 2	Select	Select	Select
GV-04-11-1	new comment	red-6-3	Pair4	Pair11	Shaft1-1.W10	Shaft2-2.W10	Shaft3-1.W10
				Pos. gear 1	10	12	152
				Pos. gear 2	----------	80	----------
				Pos. bear. 1	42	32	90
				Pos. bear 2	100	65	188
				rel. y to shaft 1	----------	70	210
				Select bearings	Select	Select	Select
Global definitions							
eta stage 1	1			Axial Load Bear. 1	Constraint	Constraint	Constraint
eta stage 2	1			Axial Load Bear. 2	Constraint	Constraint	Constraint

Figure 3.2-1 Interface for the administrator for defining new and modifying existing gearbox variants

Creating a new variant of a gear box is performed by combining existing shaft geometries, existing gear pairs and bearings. They have to be prepared using KISSsoft in advance and are being imported using standard Windows open file dialogs:

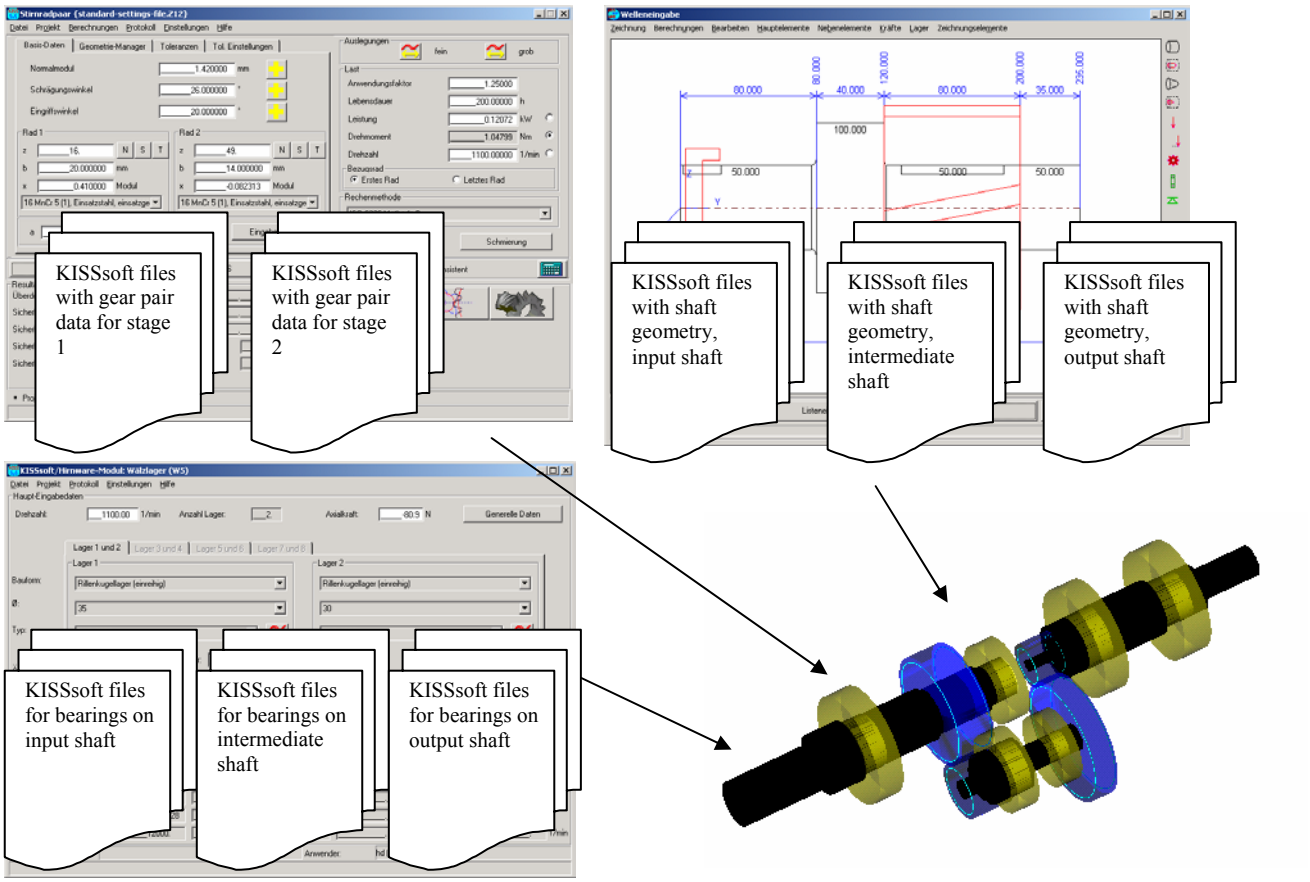

Figure 3.2-2 Building a gearbox from pre-defined KISSsoft elements

3.3 Selecting a gearbox for analysis

A variant of the gearbox is defined through its reduction and its input shaft geometry. Selecting a gearbox variant hence means that a reduction and an input shaft geometry is to be selected. This is done through selection from a list of existing reductions / shaft geometries:

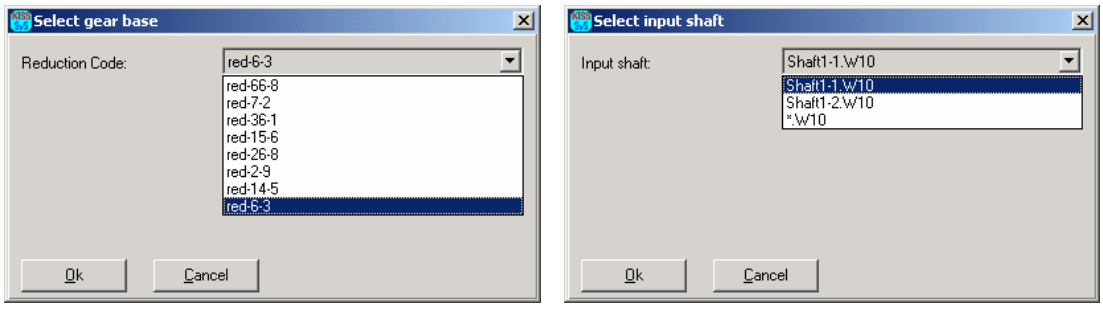

Figure 3.3-1 Selection of reduction and input shaft using dynamic lists

Based on these selections, the respective gearbox variant is retrieved from the database and is available for analysis. If the combination selected is not available of defined more than once, an error message is being issued.

3.4 Definition of external loads

The user can define the power rating (torque and speed) and apply external loads (radial/axial forces and bending moments on the input and output shaft). These loads are applied taking into account a load spectrum which in turn is read from a text file. Furthermore, parameters of the lubrication can be selected:

Selection of the gearbox

Definition of the lubrication

Loads on input and output shaft

SalesUserInterface

Select Reduction	Input/Output		Analyze	Re
red-6-3	In Speed [Upm]	Out Speed [Upm]		
Select Input Shaft	1100	175.6	Open Collective	
Shaft1-1.W10	In Torque [Nm]	Out Torque [Nm]	SINGLEcoll.TXT	
Get Gear Box	1.048	-6.5649		
GV-04-11-1	Power input	Power output		
Lubrication type	Splash Lubrication			
Oil type	Öl: EP-220			
Lub. Temp. [C]	55			
Force on Shaft 3		Force on Shaft 1		
Radial Force Fx	100	Radial Force Fx	-100	
Radial Force Fz	75	Radial Force Fz	0	
Axial Force Fy	-50	Axial Force Fy	25	
Moment Tx	15	Moment Tx	0	
Moment Tz	15	Moment Tz	0	
Distance, left end	5	Distance, right end	10	

Figure 3.4-1 Part of the user interface for selection of gearbox variant, definition of power and external loads, load spectra and lubrication

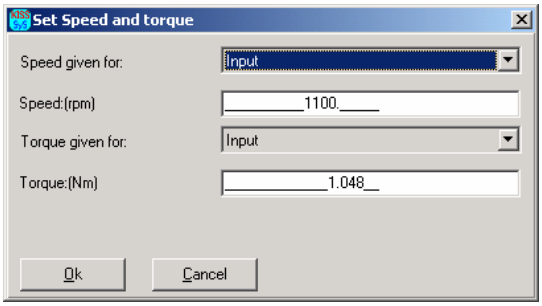

Figure 3.4-2 Dialog for definition of the power rating of the gearbox. Speed and torque can be defined on the input or the output shaft

The load spectrum is read from a simple text file. In this application presented here, the load spectra is applied on the power rating and on the external forces/moments on the input and output shaft. The number of steps in the spectra is not limited and changes in the sense of rotation can be considered.

3.5 Presentation of results

In the user interface, a summary of the analysis results is shown. Here, the lifetimes of the bearings and the gears (for flank and foot) are shown. If more detailed information is required, comprehensive protocols are available for all KISSsoft calculations. Of course, these protocols can be created in different languages (German, English, Italian and French).

fetime bearings [h]				
Mod. Calc. Method	no	no	no	
Shaft 1	Shaft 1	Shaft 2	Shaft 3	
Left bearing	49724	141.74	8.4744e+005	
Right bearing	2.5693e+005	141.74	1.0054e+006	
Tooth life [h]				
	Stage 1, Gear 1	Stage 1, Gear 2	Stage 2, Gear1	Stage 2, Gear 2
Foot	9e+099	3.1714e+006	9e+099	5375
Pitting	25.038	328.63	478.97	2862.7
Scoring Safety [-]				
	Stage 1	Stage 2		
Integral Temp.	5.1308	6.3531		
Flash Temp.	7.2237	12.164		

Figure 3.5-1 Summary of results: Lifetime for all six bearings and the three gears. Furthermore, safety factors against scoring are shown

4 Conclusion

An expert system for two stage co-axial gearboxes allows for a simple assembly of analysis models of different variants of a gearbox using pre-defined gear pairs, shafts and bearings. These variants of a gearbox are managed in a database. The user can select an existing gearbox variant and analyse it under complex loads and load spectrum. Selecting a gear box, definition of loads and execution of analysis usually takes less than three minutes!
Using this KISSsys model, the user, e.g. a sales representative, is in the position to perform a complex strength analysis using customer-specific loads when visiting a customer.

The application can be modified for other gearboxes (e.g. three stages or planetary gearboxes).